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A COMPOUND COUPLING

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A COMPOUND COUPLING

FIELD OF THE INVENTION

The present invention generally relates to an apparatus and method for mounting a component in an apparatus and more particularly relates to a mounting apparatus and method for positioning of components in an optical subsystem that is subject to thermal excursions between idle and operating temperatures.

BACKGROUND OF THE INVENTION

In electronic imaging devices, separate color paths are typically used for directing monochromatic light to image sensing or to image forming components. In the illumination path for such devices, a color separating prism is often used to provide, from a single high-intensity white light source, monochromatic red (R), green (G), and blue (B) light along separate paths. Types of color-separating prism well known in the electronic imaging arts include X-cubes or X-prisms and related dichroic optical elements, such as those disclosed in U.S. Patent Nos. 5,098,183 (Sonehara) and 6,019,474 (Doany et al.) A Philips prism, such as that disclosed in U.S. Patent No. 3,202,039 (DeLang et al.) may also be used in color separator applications.

Color separator prisms are just one exemplary type of optical device that must be precisely positioned within an optical subsystem in order to provide accurate imaging. Unless some type of positional compensation is provided, temperature changes that occur during equipment warm-up or during extended operation can cause shifting of a color separator prism, or of similar components, with respect to an intended optical path. In apparatus using a high-energy illumination source, for example, heat generated from the illumination source and from other equipment sources can cause ambient and chassis temperatures to change over time. Due to mechanical hysteresis effects, transitions in temperature can cause undesirable repositioning of mounted components during temperature transitions or excursions. Because of this, even where careful warm-up procedures are followed for achieving suitable operating temperature for an optical subsystem, some shifting or slippage of a prism or lens mount can occur. This results in undesirable shifting of the paths of modulated

light, possibly requiring constant recalibration and readjustment in order to maintain pixel-to-pixel registration between color paths.

Referring to Figure 1, there is shown a simplified block diagram of optical paths within a conventional telecine apparatus 10. Telecine apparatus 10 is used to obtain a digital red, green, blue (RGB) image from each frame 26 of a motion picture film 24. A polychromatic light source 12, such as a high-intensity Xenon lamp, directs light through frame 26 and through a lens 22 to direct the image-bearing light to a color separator prism 20, represented as a Philips prism in Figure 1. Color separator prism 20 separates RGB color components of frame 26 and directs modulated light to the appropriate red sensor 30r over red optical axis O_r, to green sensor 30g over green optical axis O_g, or to blue sensor 30b over blue optical axis O_b, for obtaining the digital image. In a typical telecine apparatus 10, red, green, and blue sensors 30r, 30g, and 30b are linear devices, each obtaining a single line of the frame 26 image at a time. Film 24 is moved in a direction D across the optical path, enabling a full scan of each frame 26. It must be emphasized that the block diagram of Figure 1 is highly simplified; a number of other types of supporting optical components may be used for further conditioning illumination or modulated light within telecine apparatus 10, as is well known to those familiar with telecine apparatus design.

As can be readily appreciated from the block diagram of Figure 1, light source 12 must generate a substantial amount of light, since the light used for image sensing is split into three separate optical paths. Light source 12, therefore, may generate a significant amount of heat during operation of telecine apparatus 10. It can be appreciated that there is a temperature excursion during the interval that begins when telecine apparatus 10 is switched from an initial off-state and ends when a suitable, stable operating temperature is reached. Another significant temperature excursion occurs as telecine apparatus 10 equipment cools from operation to an idle state. During such temperature excursions, ambient temperatures, component temperatures, and temperatures of mounting structures and surrounding supporting structures change at different rates, depending on factors such as materials used, cooling methods, and open space provided around components. With reference to the optical arrangement of Figure 1, temperature

excusions place demands on the external mounting arrangement for color separator prism 20. In particular, mechanical drift and stresses from external mounting components, experienced during temperature transitions, must be minimized to prevent unwanted movement of color separator prism 20 with respect to the color paths of red optical axis O_r, blue optical axis O_b, and green optical axis O_g.

Conventional prism mounting techniques for color separator prisms and other heat sensitive prism applications are characterized by mechanical complexity, over-constraint, crowding, and need for precision adjustment and liberal allowed tolerances for heat effects. For example:

U.S. Patent No. 6,181,490 (Wun et al.) discloses an adjustable optical frame used for a prism in an optical combiner application in which a prism is enclosed within a complex sheet metal frame that provides multiple constraints on prism movement and expansion and has numerous adjustments;

U.S. Patent No. 3,848,973 (Merz et al.) discloses a prism holder for use in a light deflection system, in which a compression mounting assembly is employed;

U.S. Patent No. 5,749,641 (Brice et al.) discloses a color combiner or separator prism enclosed on five sides within a complex frame structure having multiple sections, with some frame sections used to support mounting of other optical components;

U.S. Patent No. 6,141,150 (Ushiyama et al.) discloses a dichroic prism mounting method using oversized components, requiring complex alignment procedures and presenting demanding adhesive requirements; and

U.S. Patent No. 6,010,221 (Maki et al.) discloses a prism mount for a projection apparatus, using a diecast holding member that surrounds the prism in an arrangement that would not be optimal for applications undergoing thermal transitions and may over-constrain the prism.

As a rule of thumb, the literature for prism mounting generally recommends using some type of kinematic configuration, such as mechanical compression, as is discussed in *Handbook of Optical Engineering*, Anees Ahmad, Editor, CRC Press, New York, NY, 1997, pp. 202-210. However, attempts to provide suitable prism mounting using spring forces, frames, or other kinematic mechanical constraints have proved inadequate to the task of providing a stable mount for many types of color separator prism 20 in telecine apparatus 10, primarily due to sliding friction at kinematic contact points, caused by thermal expansion of dissimilar materials at different rates. Because color separator prism 20 is fabricated as an assembly of glued prism components, mounting schemes should minimize, equalize, or eliminate mechanical stress on glued seams where possible. Unwanted stress birefringence occurring due to constraining forces applied against any prism surface, should also be minimized.

Mechanical hysteresis resulting from temperature transitions is a recognized problem with the optics path of conventional telecine apparatus 10 as shown in Figure 1. With conventional types of telecine apparatus 10, for example, suitable warm-up time must be provided in order to achieve the proper operating temperature. As internal temperatures rise toward operating temperature, some shifting of optical components invariably occurs, which can have adverse effects on image registration. The crux of the problem is that once the proper operating temperature is reached, optical components may not return to a precise position, due to some degree of temperature-related mechanical hysteresis. Instead, sliding friction may result in an undesirable repositioning of color separator prism 20 relative to red optical axis O_r, blue optical axis O_b, and green optical axis O_g. This sliding friction can occur even when kinematic mounting techniques are employed. As a result, pixel-to-pixel registration between the color optical axes can be shifted, causing undesirable color fringing in printed frames 26. Conventional mounting and fastening techniques for color separator prism 20 have yielded poor results due to temperature-related mechanical hysteresis with telecine apparatus 10.

Flexure mounting is known for use in applications where various types of optical components must be mounted in relatively precise positions, yet

need some degree of freedom. Conventional techniques and general principles for flexure mounting of mirrors and prisms are given by Paul R. Yoder, Jr. in *Opto-Mechanical Systems Design*, Marcel Dekker, Inc., New York, 1986, pp. 205-209. Some examples of conventional flexure coupling schemes for optical components are disclosed in U.S. Patent Nos. 5,801,891 (Lloyd); 4,850,674 (Hasselskog); and 5,550,669 (Patel). Using this type of mount, each flexure blade or strut exhibits stiffness with respect to forces applied along its length, but allows bending in response to forces applied orthogonal to its length. This allows some degree of freedom for movement in some directions, while restricting movement in the length direction.

While flexure mounts have proven utility for maintaining positional accuracy to prevent unwanted shifting of components in many types of applications, adaptation of this type of mounting to thermal excursion applications introduces additional requirements. For example, in considering telecine apparatus 10 of Figure 1, it is necessary that color separator prism 20 have precisely the same position following a temperature excursion to operating temperature. That is, mechanical hysteresis effects must be eliminated with respect to operating temperature. Ideally, at any given temperature T_n during its excursion to or from operating temperature, color separator prism 20 should have the same relative position P_n. It can be readily appreciated that achieving this type of temperature-dependent positional accuracy would be particularly beneficial. Among the challenges that complicate such a solution is the likelihood that color separator prism 20 and its associated mounting hardware exhibit a coefficient of thermal expansion (CTE) that is different from the CTE of supporting chassis components.

Thus, it can be seen that there is a need for a mounting apparatus and method for coupling a prism or other optical component to a supporting structure that maintains positional accuracy of the prism or other optical component as a function of temperature conditions.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a compound coupling for mounting a component having a first coefficient of thermal

expansion (CTE) to a support structure having a second CTE, the compound coupling comprising a first flexure coupling, a second flexure coupling, and a third flexure coupling, each flexure coupling extends from the support structure to the component and each of the flexure coupling:

(a) is attached to the support structure at a first and a second mount point;

(b) is attached to the component at a component mount point; and

(c) has a flexure CTE substantially equal to the second CTE.

It is a feature of the present invention that it provides a three-point suspension mounting using a V-flexure arrangement suitably arranged for each point.

It is an advantage of the present invention that it presents minimal obstruction to air flow for cooling the component.

It is an advantage of the present invention that it provides a mechanical mounting solution that is mechanically simple and robust.

It is a further advantage of the present invention that it controls component position as a function of temperature. Using the compound coupling solution of the present invention, a component is restored to a precise position according to desired temperature conditions.

It is yet a further advantage of the present invention that it provides a relatively low-cost solution for suspension mounting of a component, such as an optical component.

These and other objects, features, and advantages of the present invention will become apparent to those skilled in the art upon a reading of the following detailed description when taken in conjunction with the drawings wherein there is shown and described an illustrative embodiment of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

While the specification concludes with claims particularly pointing out and distinctly claiming the subject matter of the present invention, it is believed that the invention will be better understood from the following description when taken in conjunction with the accompanying drawings, wherein:

Figure 1 is a schematic block diagram showing the arrangement of optical components in a telecine apparatus of the present invention;

Figure 2a is a simplified perspective view showing the conceptual arrangement of a flexure coupling according to the present invention;

Figure 2b is a simplified perspective view showing the conceptual arrangement of an alternate embodiment of a flexure coupling according to the present invention;

Figure 2c is a simplified perspective view showing the conceptual arrangement of another alternate embodiment of flexure couplings according to the present invention;

Figures 3a, 3b, and 3c are side views showing the response of flexures of the present invention to thermal expansion for dissimilar materials;

Figure 4 is a perspective view showing a prism mount according to the present invention;

Figure 5 is a plane view of a prism mount according to the present invention;

Figure 6 is a side view of a prism mount according to the present invention; and

Figure 7 is a perspective view, from the side, of a prism mount according to the present invention.

DETAILED DESCRIPTION OF THE INVENTION

The present description is directed in particular to elements forming part of, or cooperating more directly with, apparatus in accordance with the invention. It is to be understood that elements not specifically shown or described may take various forms well known to those skilled in the art.

Referring to Figure 2a, there is shown the basic arrangement of components served by a flexure coupling 40 of the present invention. For simplicity, only one flexure coupling 40 is shown in Figure 2a. Flexure coupling 40 is part of the compound coupling used to mount a component 60 to a base 62 or other support structure, such as a chassis plate, for example. In a preferred embodiment, flexure coupling 40 comprises a pair of struts 42, 44 that extend from mount points 66 and 68 on base 62 to a mount point 64 on component 60. A

fastener 70, such as a screw or bolt, is typically used to attach struts 42, 44 to mount points 64, 66, 68. In the configuration of Figure 2a, flexure coupling 40 thereby forms a V-mount.

Base 62 and component 60 have different CTE values, as shown in Figure 2a. In the configuration of Figure 2a, struts 42 and 44 have substantially the same CTE as base 62 (that is, CTE #1). With this arrangement, the open end of the V-mount (that is, the side at which struts 42 and 44 have separate mount points 66, 68 is at base 62.) Common mount point 64 is at the vertex of the V-mount. It can be seen that expansion of base 62 when heated also affects the positions of mount points 66 and 68. Flexure coupling 40 allows this physical expansion and allows controlled movement of component 60. During a temperature excursion, the combined action of three flexure couplings 40, as is described herein below, restores component 60 to a position that is a function of temperature. At any temperature T_n within the temperature excursion range, component 60 is disposed at a specific corresponding position P_n. This means that repeatable positioning can be obtained at an operating temperature, so that, following any upward or downward excursion, once an operating temperature is reached, component 60 is restored to the same position held at the last time that same operating temperature was reached.

Referring to the alternate embodiment of Figure 2b, there may be conditions under which an additional strut 44 is fitted between mounting points 66 and 68, such as for improved stability.

Referring to the alternate embodiment of Figure 2c, another alternate embodiment is shown, wherein a single sheet flexure 72 is employed as flexure coupling 40. With this arrangement, sheet flexure 72 also has a CTE that is substantially equal to the CTE of base 62, using the same principle described with respect to Figure 2a.

Referring to Figures 3a, 3b, and 3c, there is shown, in exaggerated form, how flexure coupling 40 of the present invention operates to compensate for differences in CTE between component 60 and base 62 during a temperature excursion. Here, flexure coupling 40 has the same CTE as base 62, while component 60 has a relatively much lower CTE. Figure 3a shows flexure

couplings 40 supporting component 60 from base 62 at a reference temperature. Figure 3b shows what would happen at an elevated temperature, if there were no attachment of flexures 40' (shown in phantom) to a base 62' (shown in phantom) at this temperature. Due to thermal effects, there is noticeable expansion of flexures 40' and base 62' as shown; however, component 60, with a much lower CTE, exhibits almost no expansion. Base 62' grows larger in each dimension, as do flexures 40'. The reference temperature state in Figure 3a is for comparison with the response to elevated temperature shown in Figure 3c. In Figure 3c, there is shown how flexures 40, when attached between base 62 and component 60, operate to eliminate hysteresis effects, by bending in a widthwise direction. This ability to bend gives the arrangement of flexure couplings 40 an advantage over other types of coupling methods, particularly over methods that, due to temperature excursion, allow sliding friction and, therefore, allow consequent shifting of position.

Referring to Figures 4-7, there is shown a compound coupling using three flexure couplings 40 for color separator prism 20, suitable for use within telecine apparatus 10. A surface of color separator prism 20 is mounted to a prism mounting plate 34. In one embodiment, prism mounting plate 34 is a metal plate glued to a surface of color separator prism 20. The material used for prism mounting plate 34 is selected to have a coefficient of thermal expansion (CTE) compatible with that of the glass components of color separator prism 20, a Philips prism as shown in Figure 4.

Prism mounting plate 34 has three strut junction mounting points 52, two of which are visible from the perspective view of Figure 4. Extending from each strut junction mounting point 52 is a pair of struts 42, 44, which provide a V-shaped flexure coupling 40 between prism mounting plate 34 and a chassis mounting plate 36 that is securely mounted onto a chassis 50. Strut 44 extends from strut junction mounting point 52 to a strut mounting point 48. Strut 42 extends from strut junction mounting point 52 to a strut mounting point 46. Using this arrangement for strut junction mounting points 52, three separate V-shaped flexure couplings are provided between prism mounting plate 34 and chassis mounting plate 36. As was described with reference to Figures 2a and 3a-

3c, the CTE of struts 42, 44 is equal to, or very nearly equal to, the CTE of chassis mounting plate 36.

By using the V-flexure structures of the present invention as flexure coupling 40, and using the same, or closely matched, materials for struts 42, 44 and chassis mounting plate 36, hysteresis effects of thermal expansion are minimized. Struts 42 and 44 are rigid along their lengths, but can bend under stress, as is shown in Figure 3c, such as under conditions of thermal expansion of prism mounting plate 34 or of chassis mounting plate 36. This flexibility allows each flexure coupling 40 to restore color separator prism 20 to proper position following temperature transition, such as following power-up, for example. No mechanical slippage due to sliding friction is permitted by flexure coupling 40. By using three separate flexure couplings 40 as this compound coupling solution, the present invention constrains movement of color separator prism 20 in any direction, without applying over-constraint. Depending on the type of application, two flexure couplings 40 could be used as part of a compound coupling solution, but without the inherent 3-dimensional constraint and precise maintenance of position with respect to temperature of a solution using three flexure couplings 40.

Using either V-flexures (as in Figures 2a, 2b, and 4-7) or a single sheet flexure 72 (as in Figure 2c), there are three mount points for each flexure coupling 40. Two mount points are used on the element that matches the CTE of flexure coupling 40 components. For the configurations in Figures 2a, 2b, 2c, 3a, 3b, 3c, and 4-7, the CTE of flexure coupling 40 matches that of chassis mounting plate 36 or base 62. However, it must be observed that there could be alternate embodiments where it is advantageous to have the CTE of flexure coupling 40 match that of component 60 or prism mounting plate 34. For such an embodiment, the V-flexure orientation would then be reversed, with two mount points on component 60 and a single mount point on chassis mounting plate 36 or base 62.

The invention has been described in detail with particular reference to certain preferred embodiments thereof, but it will be understood that variations and modifications can be effected within the scope of the invention as described above, and as noted in the appended claims, by a person of ordinary skill in the art

without departing from the scope of the invention. The present invention could be applied for positioning an image sensor, such as a CCD sensor, for example. It must be observed that the apparatus and methods of the present invention could be applied for prisms and optical components in many types of applications, including color separation and color combining, as well as for components not having an optical function. As an alternative to mechanical fasteners, an adhesive may be suitable for securing flexure strut attachment at one or more mounting points.

The apparatus and methods of the present invention are particularly useful in applications where it is necessary to couple a component with a base support where these two devices have different CTE values.

Thus, what is provided is an apparatus and method for flexure coupling of an optical component that is resilient to temperature excursions.

PARTS LIST

10	telecine apparatus
12	light source
20	color separator prism
22	lens
24	film
26	frame
30r	sensor, red
30g	sensor, green
30b	sensor, blue
34	prism mounting plate
36	chassis mounting plate
40	flexure coupling
40'	flexures
42	strut
44	strut
46	strut mounting point
48	strut mounting point
50	chassis
52	strut junction mounting points
60	component
62	base
62'	base
64	mount point
66	mount point
68	mount point
70	fastener
72	sheet flexure